US Army Corps
of Engineers

Construction Engineering
Research Laboratory

USACERL Technical Report M-91/02
October 1990
Design Concepts Using Advanced Materials

Exterior Insulation and Finish Systems (EIFS) on U.S. Army Facilities: Lessons Learned

by
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This report provides an analysis of problems encountered with EIFS, and recommendations for correcting and preventing such problems in new and existing facilities. The four main problems areas with EIFS were:

1. Mechanical damage
2. System cracking
3. Design issues
4. Construction deficiencies.

It was found that most problems with EIFS were minor, and that all problems could be either prevented or corrected by relatively simple maintenance and repair procedures.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave Blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	October 1990	Final

4. TITLE AND SUBTITLE

Exterior Insulation and Finish Systems (EIFS) on U.S. Army Facilities: Lessons Learned

5. FUNDING NUMBERS

PE 4A162731
PR AT41
WU MA-CR0

6. AUTHOR(S)

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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

U.S. Army Construction Engineering Research Laboratory (USACERL)
PO Box 4005
Champaign, IL 61824-4005

8. PERFORMING ORGANIZATION REPORT NUMBER

USACERL TR M-91/02

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

HQUSACE
ATTN: CEMP-ES
20 Massachusetts Avenue, NW.
Washington, DC 20314-1000

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

Copies are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

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This report provides an analysis of problems encountered with EIFS, and recommendations for correcting and preventing such problems in new and existing facilities. The four main problems areas with EIFS were: (1) mechanical damage, (2) system cracking, (3) design issues, (4) construction deficiencies.

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14. SUBJECT TERMS

Exterior Insulation and Finish Systems
EIFS — insulation
walls — lessons learned

15. NUMBER OF PAGES 48

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	SAR

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std 239-18
298-102

FOREWORD

This work was performed for the Directorate of Military Programs, Headquarters, U.S. Army Corps of Engineers (HQUSACE), under Project 4A162731AT41, "Military Facilities Engineering Technology"; Work Unit MA-CR0, "Design Concepts Using Advanced Materials." The HQUSACE Technical Monitor was Rodger Seeman, CEMP-ES.

This work was completed by the Engineering and Materials Division (EM) of the U.S. Army Construction Engineering Research Laboratory (USACERL). Dr. Paul A. Howdyshell is Acting Chief, USACERL-EM. Mr. Richard Lampo was the principal investigator. The USACERL technical editor was Mr. William J. Wolfe, Information Management Office.

COL Everett R. Thomas is Commander and Director of USACERL. Dr. L.R. Shaffer is Technical Director.

CONTENTS

TABLE

FIGURES

FIGURES (Cont'd)

EXTERIOR INSULATION AND FINISH SYSTEMS (EIFS) ON U.S. ARMY FACILITIES: LESSONS LEARNED

1 INTRODUCTION

Background

The use of exterior insulation and finish systems (EIFS) on Army facilities has increased substantially over the past 10 years, largely due to cost effectiveness over other exterior wall systems, insulation efficiency, and/or the low-maintenance, stucco-like finish. The performance of these systems, however, has not always been as expected. Major failures such as system delamination and extensive cracking have occurred on Army facilities in recent years, chiefly caused by design and/or installation deficiencies. An analysis of the problem with EIFS is needed to provide guidance in preventing future occurrence of major system failure.

Objective

The objective of this report is to outline some of the problems that have occurred with these systems and present recommendations that will help correct and eliminate these problems in existing and future installations.

Approach

On-site inspections were made at several Army and Air Force bases where EIFS have been used. Problems and successes were documented. Available information on the type of system, age of system, conditions at the time of application, and the manufacturer of the system were recorded.

Mode of Technology Transfer

The technical issues documented by this work effort will be included, as appropriate, in future updates of the Corps of Engineers Guide Specification, CEGS-07240, *Exterior Insulation and Finish Systems.*[1]

[1] CEGS-07240, *Exterior Insulation and Finish System* (Headquarters, U.S. Army Corps of Engineers [HQUSACE], December 1988).

2 EIFS CHARACTERISTICS

EIFS are nonload-bearing exterior wall cladding systems that can be used effectively in new construction or retrofit applications (Figures 1 through 4).* These systems usually contain (shown schematically in Figure 5):

1. Molded expanded polystyrene insulation board (MEPS) (commonly referred to as "bead board") or extruded expanded polystyrene insulation board (XEPS) (commonly referred to as "blue board")

2. An adhesive or mechanical attachment of the insulation board to the substrate or both mechanical and adhesive attachments

3. A fabric-reinforced, or a fabric- and chopped fiber-reinforced base coat

4. An acrylic "stucco type" or aggregate finish coat.

These systems are traditionally separated into the following two classes:

1. Polymer-based (PB) systems

2. Polymer-modified (PM) systems.

Occasionally, the term "hard coat" is used to describe PM systems and "soft coat" to describe PB systems. However, these terms imply inaccuracies about the systems' mechanical properties, which are mainly dictated by the mechanical properties of the reinforced base coat. By virtue of the thick cementitious base coat, PM systems are hard. PB systems, on the other hand, vary in their properties depending on their base coat composition. For some PB systems, cement is added to the base coat mixture before application. These PB systems will be harder and more brittle than PB systems without cement. To avoid confusion, the industry discourages the use of the hard coat or soft coat terms.

PB Systems

PB systems are most commonly applied over MEPS insulation board, which is adhesively attached, or adhesively and mechanically attached to the substrate.

The PB system base coat may be a polymer-cement mix or all polymer-based. The thickness of the base coat varies depending on the number of layers and the type of reinforcing fabric used. The thickness of the base coat ranges from about 1/16 in. to 1/4 in.** The reinforcement is typically a polymer-coated glass fiber mesh, which is embedded into the base coat at the time of installation.

The finish coats for PB systems are available in a wide variety of textures and colors.

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*All figures included at end of text.
**1 in. = 25.4 mm.

PM Systems

PM systems are most commonly applied over XEPS insulation board, which is mechanically attached to the substrate.

The PM system base coat is generally a polymer-modified cementitious mixture. The thickness of the base coat ranges from 1/4 to 3/8 in. The reinforcing fabric is generally a polymer-coated glass fiber mesh, which is mechanically attached to the insulation board prior to the application of the base coat. This mesh serves not only to reinforce the base coat but also to aid in adhering the base coat to the insulation board. The base coat may also be additionally reinforced with chopped glass fibers.

As with the PB systems, the finish coat in PM systems is applied over the base coat and is available in a variety of colors, textures or aggregate finishes.

System Assemblage

Although panelized systems (where factory-made EIFS panel sections are attached to the wall via mechanical tracks) are available, such systems are used less frequently since they cost more than on-site constructed systems. The majority of EIF systems are constructed in the field on the building wall. The basic construction sequence is as follows:

1. Foam insulation boards of the appropriate thickness are attached to the substrate wall. For PM systems, the boards are usually attached using mechanical fasteners. For PB systems, the boards are typically attached adhesively, although mechanical fasteners or a combination of mechanical fasteners and adhesives may be used where desired or needed.

2. After appropriate adhesive curing, the system base coat is applied over the attached insulation boards. For PB systems, the specified reinforcing mesh is then worked into the wet base coat. (For PM systems, the reinforcing mesh is mechanically attached in the same operation of attaching the boards.) If more than one layer of mesh is specified, the procedure is repeated after allowing the previous layer to cure.

3. When the base coat layer has appropriately cured, the system finish coat is applied.

System Advantages

One advantage of EIFS is they offer very good insulating properties. Because these systems are applied to the exterior of a building, they eliminate thermal bridging to the outside caused by floors or ceilings. They also greatly decrease the thermal shock, or temperature range, that the structural load-bearing wall experiences, which helps to prolong the lifetime and reduce maintenance to the wall.

Another advantage of EIFS is that they are cost efficient; the systems may pay for themselves in energy savings in just a few years. Life cycle costs are low because the systems require little maintenance, such as periodic painting. Also, since they are applied to the exterior of a building, normal operations within the building need not be stopped or altered during the installation of the system. EIFS can also improve the aesthetic appearance of buildings (Figures 3 and 4). The wide range of finish coats available give the designer/architect ample freedom in choosing colors and designs to enhance the building architecture (Figures 1 and 2).

EIFS are easily applied and can be installed in a relatively short time. They can also be installed over a wide range of substrates, which greatly increases their versatility.

Considerations for System Use

All components of EIFS function together to provide insulation, weather/moisture protection, durability, and an aesthetically pleasing appearance. EIFS are designed to be a moisture barrier; however, if water enters the system, its integrity can be affected. Therefore, deficiencies that allow water penetration are of major concern. Examples of such problem areas are presented in the next chapter.

EIFS were introduced into the U.S. market about 15 years ago, and therefore represent a relatively new technology. Procurement/guide specifications for EIFS will need to be periodically updated using lessons learned from actual installations, and manufacturer input as the industry evolves and improves its products (to remain competitive with other exterior wall cladding systems). Since satisfactory system performance depends on proper application procedures, field inspectors must become aware of critical deficiencies that could lead to future problems. The following chapter outlines some of these critical deficiencies and the reasons or causes for their occurrence. Recommendations are also given for preventing these problems before they occur or for correcting them after they have occurred.

3 LESSONS LEARNED IN EIFS APPLICATIONS

In applying EIFS to buildings on Army and Air Force bases, several recurring problems have arisen, most of them minor and preventable. The few major system failures observed also could have been prevented with proper system design and adequate construction inspection. This section identifies these problems and gives recommendations for preventing or correcting them. The problems are broken down into the following basic categories:

1. Mechanical damage
2. System cracking
3. Design issues
4. Construction deficiencies.

Some specific problems may fall under more than one of these headings. For example, some mechanical damage can be eliminated by appropriate design considerations. With this in mind, specific problems are listed under the category that had the most bearing on or best described the problem. Cross-references to other headings are made where appropriate. A summary of problems and proposed solutions is included in Table 1, at the end of this chapter.

Mechanical Damage

Description

Mechanical damage is damage to the system caused by any physical object striking, cutting or abrading the system. This type of damage is of concern if the base coat, reinforcing fabric, or insulation board is exposed (Figure 6). Damage of this sort may allow moisture to penetrate the system, which can reduce its insulating properties and possibly lead to further degradation. Water penetration can also cause deterioration of the structural, load-bearing wall. By nature of the system composition (typically, a high-modulus, hard but relatively thin shell applied over a relatively low-modulus, soft foam layer), mechanical or impact damage is an inherent problem. Appropriate measures must be taken to lessen the potential for such damage whether its cause is intentional or unintentional.

Intentional

Deliberate acts of vandalism where the EIFS was mechanically damaged were seen frequently on the site visits. Typically the damage was caused by personnel throwing rocks or gouging the system with sharp objects. In a hidden area of one building, a soldier had even carved his initials into one of the softer type systems. More innocent damage has been caused by personnel bouncing baseballs against the buildings. Overall, the damage caused by throwing rocks or other objects is small compared to the total wall area on the buildings to which EIFS is applied.

Of greater concern is the intentional damage observed in areas where personnel congregate or wait in line (Figures 7 and 8). When the base coat and finish coat layer is broken by a sharp blow or impact, it makes a very distinct noise, caused by its attachment to the underlying foam. Once this wall is kicked, others may joint in to duplicate the sound. If boredom, anger, or nervous fidgeting has a chance to take over, the system can be literally picked apart as personnel dig at the previously damaged areas. Large areas of the system can be lost and the entire wall becomes unsightly (Figures 7 and 8).

Unintentional

Probably the most common example of unintentional damage is that caused by lawnmowers or other maintenance equipment scraping or striking the wall (Figure 9). Rocks and other debris thrown by mower blades have even been observed embedded in the system.

Doors and door knobs can also cause damage to EIFS when doors are opened too wide due to door stops being absent or not repositioned to account for the added wall thickness of the installed EIFS (Figures 10 and 11).

Figures 12 and 13 demonstrate that EIFS applied in loading dock areas typically had sustained extensive damage from trucks moving in and out, and the action of loading and unloading freight. This issue is discussed further in the section on design issues.

Natural causes such as hail storms have also caused damage to EIFS (Figures 14 and 15). The force of this particular storm was very intense with virtually every automobile in the vicinity sustaining impact damage from the golf ball to baseball-sized hail. Hail stones punctured and broke the EIFS, particularly on flat horizontal areas such as the top of parapet walls (Figure 14) and along the horizontal edges at the window cutouts (Figure 15). Even on some of the vertical wall surfaces, permanent indentations were made where the hail failed to break through the base coat/finish cast layer, but crushed the underlying foam. Although the damage to this building was extensive, other nearby buildings on which EIFS were applied were not damaged. A contributory factor to this situation is that (based upon on-site cursory examinations) the reinforced base coat was applied much more thinly than required by the manufacturer. The damage observed would probably have been less had a proper thickness of base coat been applied.

Solutions/Prevention

As a first approach to the prevention of mechanical damage to EIFS, a high impact system should be specified, especially for high traffic areas. Certain buildings may require high impact EIFS on the lower stories where the type and use of the building create a high potential for such damage. Most manufacturers offer standard and high impact options such that the high impact resistant system may be specified for locations that require it. The high impact and standard impact resistant areas are indistinguishable once the building is finished.

It should be noted that the impact resistance of the various systems covers a wide range. As yet, no standardized guidance is available to compare the different manufacturers' high impact systems. One manufacturer's high impact system is not necessarily equal to another manufacturer's high impact system.

For particular problem areas (Figures 7 and 8), another siding material less prone to mechanical damage could be specified in place of or over the EIFS. For example, solid masonry, brick, or wood paneling (wainscot) could be architecturally blended into the wall at the anticipated problem areas. The small loss in energy efficiency where brick or masonry is used instead of EIFS should be compensated for by the reduced maintenance problems for the total areas affected. If the problem is abrasion, contact with the abrading object must be restricted or a special wear surface provided.

As previously mentioned, door stops must be used and appropriately positioned to eliminate the possibility of the door handle or the door itself striking the system (Figure 16). On retrofit applications, the original door stop may need to be repositioned to account for the increased wall thickness.

Damage caused by lawnmowers or other yard maintenance equipment can be lessened by providing a gravel rock border around the buildings as shown in Figure 17. Shrubbery can also be used as long as it is not of the climbing variety, which can actually penetrate into some systems.

The impact damage caused by the hail storm raises two important points: (1) the importance of sufficient thickness of the base coat and (2) the inadequacy of EIFS to function as a roof (Figure 14). The impact resistance of an EIFS decreases dramatically if the system is not applied per manufacturer's recommended thickness. (A base coat applied too thickly can also reduce the system impact resistance unless additional reinforcement fabric is used.) Although it may not have prevented the damage due to the hail, had the system been closer to specifications, the extent of damage would probably have been less.

EIFS were never intended to function as a roof system even for the tops of parapet walls. Assuming that hail falls more or less vertically, horizontal surfaces would receive greater hail damage than vertical wall surfaces. Furthermore, use of EIFS on level areas increases the chance for moisture infiltration into damaged wall sections.

In all cases, damaged areas where the system has been cracked or punctured should be repaired as soon as practical, certainly before moisture penetration has a chance to cause further deterioration of the wall system. The manufacturer's detailed instructions should be followed to best assure proper repair procedures. A properly repaired section should be almost indistinguishable from the surrounding wall area.

System Cracking

Description

Cracking in EIFS is a problem present to some degree at all installations. As with the mechanical damage described above, cracks in the surface can provide a path for moisture to penetrate into the system. There are several factors which can cause cracking in EIFS. System cracking will occur if applied stresses exceed the strength of the reinforced base coat layer. This usually occurs in locations where the stresses are concentrated, such as the corners around window or door penetrations (Figure 18). However, stress concentrations and cracking can occur in other locations far from corners or edges. If the insulation board has not been properly cured, it may shrink after application, which in turn may cause surface cracking. If the insulation boards are not tightly abutted, the liquid base coat can fill the gap. This creates a stress concentration which will nearly always cause a crack. Figure 19 shows cracks that outline the underlying insulation boards due to boards not being tightly abutted. Cracking is further highlighted here because of fading to the dark color of the finish coat.

The cracking shown in Figures 20 and 21 was caused by several factors. Cracking due to corner stress usually occurs along a 45 degree angle radiating from the corner (Figure 18). Figure 20 shows cracking that initiated at the corner but then proceeded vertically due to additional contributing factors. The two main factors were that: (1) the vertical edge of the insulation board beneath the window was in direct line with the vertical edge of the window, and (2) the insulation boards were not tightly abutted with gaps between the boards up to 1/2-in. wide. A further contributing factor may have been the 6-in. thick insulation used on the building. This latter issue is discussed further in the next section on design.

All of the manufacturers require system expansion/control joints wherever the system is to be placed over existing building expansion joints or comes in contact with dissimilar materials. Failure to do so will almost certainly lead to system cracking. In PM systems, control joints are required to allow for expansion and contraction of the system. Manufacturers' recommendations must be followed.

Actually, these problems could be classified as construction deficiencies since they could have been prevented by proper system application. The specific examples listed here emphasize the mode of failure. (Also see the section on construction deficiencies.)

Solutions/Preventions

Most of the cracking in EIFS due to these common causes could be prevented. To lessen the occurrence of corner-initiated cracking, most manufacturers now require that diagonal pieces of reinforcing fabric be placed at the corners of windows and doors (Figure 22). Also, the insulation boards should be placed so that the vertical edges of the board do not line up with the vertical edges of the window, door, or other such wall penetrations (Figure 23).

To prevent cracking due to dimensional changes in the insulation board, the manufacturer's guidelines and the Corps of Engineers Guide Specification, CEGS-07240, should be followed as to the type and quality of boards to be used. Any insulation board that does not meet these requirements should be rejected. Applicators must use care (especially for PB systems) to assure that the insulation boards are all tightly abutted (both vertically and horizontally). If gaps still exist between the boards, slivers of insulation board must be inserted per the manufacturer's recommendations. Base coat material must not be used to fill these gaps. Follow the manufacturer's recommendations to determine the maximum allowable gap not requiring these corrective actions.

In PM systems, the manufacturer's guidelines for the proper spacing of control joints must be followed. When expansion joints or discontinuities occur in a building, the manufacturer's details should be followed or the manufacturer should be consulted for recommendations.

Proper corrective action for cracks on existing systems first requires an analysis of why the cracking occurred. The cause of the cracking must be identified and eliminated before initiating the final repair; otherwise, the crack may reoccur. For example, permanent repair of the cracking due to gaps between insulation boards would require removal of the base coat/finish coat system, and filling the gap with slivers of insulation board prior to replacement of the reinforced exterior skin. The use of latex caulking to repair systems cracks should only be used as a temporary fix. Such measures can reduce the likelihood of moisture infiltration if more permanent repairs (which require replacement of the reinforced base coat/finish coat layer) must be delayed. Permanent repairs are required to prevent crack growth beyond the temporary fix.

Design Issues

Description

Some of the problems that have occurred with EIFS installations have been caused by poor application design. This refers to the way the system is applied to a building, not to deficiencies in the manufacturer's product. One of these design problems has been in the way downspouts have been implemented. In one application, the system was bridged over downspouts. With this poor design, repair or replacement of the downspout would be difficult or impossible without removal of the system at that location. To make matters worse, the system did not freely bridge the downspout, but was adhesively attached to it.

Figure 24 shows that cracks occurred along the length of the downspout due to the differences in the thermal expansion and contraction of the two material systems. At another installation, the downspouts were recessed into the system and had a spout which directed the water away from the building. In one location shown, the spout was missing and water flowed directly onto the system (Figure 25). Water will eventually erode the finish and base coat layer, increasing the potential for water penetration into the EIFS.

EIFS should not be specified or designed as flat, horizontal sections such as the top of parapet walls previously shown in Figure 14 and the window sill area shown in Figure 26. If EIFS are to include horizontal sections, they must always be sloped so standing water will not collect.

System failures occurred at one installation where the system was applied using 6-in. thick insulation board. Although construction deficiencies were the primary cause of the system cracking, the extra thick insulation board appears to have been a contributing factor. None of the manufacturers specify the use of insulation board at thicknesses greater than 4 in. This value was set because of the added fire load (fuel contribution) of the thicker insulation. The mechanical properties of the systems are unknown for board thicknesses greater than 4 in.

In this system failure, cracking occurred where 6-in. thick insulation was applied, and where the reinforced base coat was applied as a continuous layer along the entire length of the building. Cracks occurred predominantly on the south and west side walls, which experience the greatest thermal cycling due to exposure of the sun. Corresponding cracking failures were not present where thinner (3/4- to 2-in. thick) insulation board was used and applied only between the pilasters. (Where the 6-in. thick insulation board was used, the system bridged the pilasters.) Although specific system behavior was not completely determined and understood, thermal effects relative to the thicker system were a factor, and control joints appear to be required. Control joints for PB systems are not required by the manufacturers relative to surface area (as with PM systems) or insulation board thickness. The situation indicates the need for further study into the mechanical properties of the PB systems relative to these variables.

A rather broad design issue is one where systems have been applied to areas where the possibility of damage is very high. A classic example of this is applying the system to loading docks (Figures 12 and 13). With trucks backing up, forklifts moving pallets around, and other such activities, the system is extremely liable to receive impact or puncture type damage. Even the highest impact resistant EIFS cannot stand up to this kind of abuse. System alternatives should be specified for these locations.

Another design issue is the use of EIFS over gypsum sheathing boards that meet ASTM C-79.[2] Concerns have been raised by several consultants and building owners regarding the possible degradation of the gypsum board if moisture penetrates the system. This is a special consideration for 100 percent adhesively attached systems where system debonding can occur if infiltrating moisture deteriorates the paper face of the gypsum board. Some consultants have warned that the stud wall can also sustain serious damage if wet conditions persist. Few examples of this type of system use on Army and Air Force installations were identified since most applications are retrofit applications over existing masonry. In the few examples identified on Army installations, the areas involved were small (e.g., additions added to existing masonry buildings) and not very old. However, one debonding failure over gypsum sheathing was observed on a small aircraft control tower. The failure appeared to be only on one side of the six-sided structure and at ground level only. This was a retrofit application over a painted steel-skinned structure.

[2] ASTM C-79, *Test Method for Gypsum Sheathing Boards* (American Society for Testing and Materials [ASTM], Philadelphia, PA, 1987).

Gypsum sheathing was mechanically attached to the structure and the EIFS adhesively attached to the gypsum. In one area, the EIFS was slightly bowed away from the substrate wall. When pushing on the wall, pieces of deteriorated gypsum fell from behind the system onto the ground. Moisture was suspected to be entering the system along a crack in an architectural feature running horizontally around the tower.

The use of dark finish colors for EIFS should also be specified with caution. Dark colors may exaggerate system movement due to thermal effects by absorbing more heat than lighter-colored surfaces. Although there were no special problems on the visited Army and Air Force installations where dark colors were used, some consultants have warned of problems related to foam and/or mesh deterioration caused by excessive heat build-up in the system. Also, dark colors tend to show fading more than light colors.

Solutions/Preventions

Careful attention should be paid to the treatment of gutters and downspouts in the building design. Downspouts should not be concealed. If this is not possible, the bridge section must be isolated from the adjacent wall (Figure 27) and the downspout itself. The bridge section must not be adhesively attached to the downspout. The system and the downspout must be free to move independently of each other. Any existing installations with these conditions present will need to alter the system to conform to the above recommendations. Leaking, damaged, or missing gutters and downspouts must be repaired or replaced to reduce the possibility of water infiltration into the EIFS.

As stated in the section describing the design issues, EIFS should not be installed as level, horizontal sections. If such sections are desired, as on the top of parapet walls, they must be capped with a metallic flashing. Otherwise, all horizontal sections must be sloped for water runoff. Window sills must always slope to the outside. Existing nonsloping installations require removal and reapplication of the system to add the necessary angled sections.

Future applications using insulation boards greater than 4 in. thick are not recommended until further information is obtained regarding the system behavior at such thicknesses. The existing facilities with 6-in. thick insulation will need to have expansion joints installed along the wall as well as correction/repair of the board gaps and system cracks as noted in the previous section on cracking.

As recommended in the section on mechanical damage, areas prone to mechanical damage need to use high impact resistant systems. However, in loading dock areas the use of other construction materials less susceptible to mechanical damage is recommended. Such materials include solid masonry, brick, or wood paneling (wainscot). See the previous section on "Mechanical Damage - Solutions/Prevention" for further details.

For any proposed use of EIFS over gypsum sheathing, the manufacturer's most current installation procedures/details as well as Corps Guide Specification requirements must be strictly followed. (The December 1988 CEGS-07240 requires the system to be mechanically attached when used over gypsum sheathing boards.) Premium nonpaper-faced boards may be used in place of the gypsum board. Although more expensive, the chance of system debonding is greatly reduced. For systems utilizing gypsum sheathing board (current and future), extra care should be taken to maintain a watertight skin with periodic inspection of sealants, expansion/control joints, mechanical/electrical system penetrations and any other details where water has a greater chance to enter the wall system. If system debonding is present, the cause and extent of debonding must first be determined. If water infiltration is to blame, the source of such infiltration must be eliminated before any other corrective actions are taken.

Construction Deficiencies

Description

All of the major failures investigated and even many of the minor failures were, at least in part, caused by poor or improper workmanship. Successful system performance from the standpoint of either energy efficiency or durability is dependent on proper system installation. The following examples illustrate some of the more important concerns.

For the immediate future, the majority of EIFS applications within the Army (and Air Force) will continue to be retrofit/rehab applications on masonry block buildings. The condition of the substrate surface is very important, especially for PB systems, which are adhesively applied. Most of the Army's masonry buildings have been previously painted. If the painted surface is dirty, chalky, peeling or in otherwise poor condition, the adhesive may not hold the system onto the wall. Therefore, the surface must be properly prepared, or failures will continue to occur (Figure 28). With the thickness of chalk that was present on this wall (Figure 29), the insulation boards probably should not have held in place under the strain of construction. This problem is not confined to older construction since dirty substrate surfaces on newly constructed walls can also lead to adhesive failures. Actually, the integrity of the entire substrate thickness is important. It would do no good for the system to adhere to the substrate surface if the substrate delaminated from within. Substrate integrity is also needed to provide adequate pullout strength for mechanically attached systems.

Gypsum sheathing boards may deteriorate from prolonged exposure to the weather. Overexposure may cause a breakdown in the bond between the gypsum core and the paper face. This can occur in material storage as well as after the wall is erected, but before the EIFS is applied. If deteriorated boards are used, the board face may delaminate under the load of an adhesively attached EIFS.

Insufficient adhesive contact area can be another cause of or contributing factor to major failures. Adhesively attached PB systems typically require a minimum of 50 percent adhesive contact area. A system failure at one installation had measured contact areas of less than 20 percent of some wall sections. Besides applying a sufficient amount of adhesive (Corps Guide Specification CEGS-07240 currently requires adhesive application with a notched trowel), the installer must work the board onto the substrate to spread out the adhesive and to assure complete surface contact.

Use of the wrong type of backer rod for caulk joints is a common deficiency. Manufacturers' specifications require closed-cell backer rods. Far too often, however, open-celled rods are used, which may lead to spongelike moisture uptake and retention. This softens the finish coat due to constant contact with the moist backer rod and eventually causes failure of the sealant adhesive (Figure 30). Failure of the sealant further increases the chance of water entering the system and substrate wall. Other sealant-related problems include use of the wrong type of sealant, or omission of the primer required for certain sealant systems.

Additional examples of poor workmanship or noncompliance with system specifications include:

1. Insufficient thickness of the base coat layer
2. Improperly embedded reinforcing fabric
3. Insufficient overlap of reinforcing fabric
4. Complete omission of the reinforcing fabric
5. Poor detailing around building penetrations, such as light fixtures, water outlets, railings, etc.

The base coat, reinforcement fabric and finish coat act together to provide the durable, weather resistant barrier. Proper thickness of the base coat is critical to achieving minimum system properties. A base coat that is too thin will reduce system mechanical properties and increase the potential for impact damage or cracks. The reinforcement fabric must be completely embedded. If bare fabric is showing (before the finish coat is applied), either the base coat was applied too thinly or the fabric was not properly worked into the base coat. Either of these deficiencies can diminish system properties. Requirements for base coat thickness depend on the fabric type (thickness) and number of reinforcing fabric layers. A wet application of base coat is required for each fabric layer application. Manufacturer's requirements for minimum/maximum base coat thickness must be followed.

The reinforcement fabric-base coat composite enhances tensile strength and impact resistance over a nonreinforced base coat layer. Omission of the reinforcing fabric would be detrimental to system performance. System cracking would result from just the normal building or system movements caused by thermal cycling and wind loading. Damage could also result from normally insignificant impact loadings.

The reinforcing fabric typically comes in rolls from 36 to 48 in. wide. For the many embedded fabric strips to function effectively as a single continuous piece, the fabric strips must have a minimum joint overlap of 2-1/2 in. Use of the fabric and proper overlap (with the original fabric on the surrounding wall) are just as important in a system repair procedure as in the original construction.

Poor system detailing around building penetrations (light fixtures, water outlets, electrical service inlets/outlets, etc.) was a common observation during the site inspections. In many cases the system was installed leaving large gaps, ragged surface edges and/or exposed insulation boards at the fixture-system interface (Figure 31). Such construction practices provide an easy path for water to enter the system and/or substrate wall.

One invisible construction deficiency results from applying base and finish coats containing acrylic polymer emulsions at temperatures below 40 °F.* Additionally, this temperature minimum must be maintained for at least a 24-hr period during material curing. Acrylic polymer emulsions are used in varying amounts in most EIFS to enhance the weather and moisture barrier properties of the system. However, if the temperature during application and curing falls below 40 °F, the barrier is compromised because the acrylic emulsion may cure as a porous, spongy layer. Water more easily penetrates this porous layer, possibly increasing the moisture content within the insulation board and/or the wall cavity. High moisture content decreases the insulation efficiency of the wall and may lead to substrate wall deterioration.

Some very important construction deficiencies are:

1. Insulation boards not tightly abutted
2. Omission of diagonal reinforcing fabric at penetration corners
3. Improper alignment of boards at window and door penetrations
4. Omission of required expansion/control joints.

*°C = 0.55 (°F - 32).

Solution/Prevention

Whether old or new, the substrate wall must be clean, dry, firm and otherwise suitable for the application. Manufacturer's guidance must be followed as to acceptable substrates and substrate preparation. Special attention must be paid to previously painted masonry surfaces. For adhesively attached EIFS, old paint should be completely removed by sand- or gritblasting. If the existing paint cannot be removed, an alternative attachment surface shall be provided, such as a 3.4 lb/sq yd* galvanized wire metal lath, mechanically fastened to the wall surface (Figure 32). Loose, falling, or crumbling concrete or masonry on weather-aged walls must be removed by sandblasting or other appropriate mechanical means. If the substrate surface will not accept adhesive bonding, the system should either be mechanically fastened directly to the wall or adhesively attached to a galvanized wire metal lath that has been mechanically fastened to the wall.

To determine if the gypsum sheathing boards have been exposed to the weather beyond the recommended limits, the following test should be performed:

1. Using a sharp knife or razor blade, make a 3-in. long diagonal cut in the middle of the board, sufficient to cut through the paper face and into the underlying gypsum. Make another 3-in. long cut at a right angle to the first, forming an "X."

2. Using the sharp edge of the cutting tool, carefully peel back the paper face (in one quadrant) approximately 1/4 in. from the intersection of the two lines.

3. Firmly holding the peeled edge between the thumb and the forefinger, lift the paper face as if to continue removing the facing material

4. If the paper splits cohesively so that half is still adhering to the underlying gypsum, the board has not been overly exposed to the weather or moisture. However, if the paper lifts and directly exposes the gypsum, the board has been exposed to the weather beyond the required limit and must be replaced.

To assure sufficient adhesive contact area, the appropriate notched trowel should be used and the workman should press and work the boards into the substrate. The volume of adhesive used should correspond with the manufacturer's recommended spreading rate. The use of too little material for a given building surface area can reduce adhesive contact area below requirements.

Inspectors should verify that the applicators are using the closed- rather than open-celled sealant backer rods. Open-celled backer rods already in place must be replaced. They should also determine if the system manufacturer's recommended sealant material or system has been procured and that all system components are available for use. If the system requires a primer, make sure such primer is applied. For existing deteriorated or failed sealant, complete removal and replacement with an approved sealant is recommended.

Inspectors should also routinely check to assure that the applicators:

1. Apply the thickness of the base coat corresponding with the manufacturer's recommendations for the particular system and reinforcing fabric being used

*1 lb = 0.0453 kg; 1 yd = 0.9144 m.

2. Completely embed the reinforcing fabric into the wet base coat layer (i.e., leave no bare fabric showing)

3. Use the specified type and weight of reinforcing fabric

4. Overlap abutting reinforcing fabric a minimum of 2-1/2 in.

5. Meet the 40 °F minimum temperature requirement for application and curing of the system materials.

Areas affected by failures that have occurred on existing systems due to any of the above deficiencies must be appropriately repaired.

Appropriate system finishing and/or sealing is required wherever building fixtures penetrate the system. Exposed board edges or gaps where moisture can enter must be sealed. If in doubt on how to finish the system-fixture interface, consult the system manufacturer for detailed recommendations. Repair of existing penetrations depends on the extent of the problem. In most cases, the problem could be corrected with appropriate system preparation and subsequent application of manufacturer-approved sealant material. In other situations, complete replacement and finishing of the system around the penetration may be required.

Table 1

Summary of Problem Issues and Corresponding Solutions/Preventions

Problem Category	Specific Problem Issue	Solution/Prevention	Corresponding References Text Page	Corresponding References Figure No.
Mechanical damage	Abrasion caused by moving objects	Remove moving object or place a wear surface over the EIFS	11-12	6
	Impact damage from thrown stones, baseballs, etc.	Use high impact EIFS	11-12	
	Vandalism (e.g., kicking, puncturing, etc.) in areas where personnel congregate	Use high impact EIFS; use other more resistant wall material in these locations	11-12	7,8
	Damage caused by lawn care equipment	Provide a gravel or shrubbery border around the buildings	12	9,17
	Damage caused by opening of doors	Provide or relocate doorstops	12	10,11,16
	Damage caused by loading dock activities (also see design issues)	Use other wall materials more resistant to the activities in these locations	12,15	12,13
	Hail damage (also see construction deficiencies)	Minimize use of EIFS in flat, horizontal sections. Assure proper base coat thickness	12-13	14,15
System cracking (also see construction deficiencies)	Cracking at window and door corners or other building penetrations	Use diagonal pieces of reinforcing fabric at corners	13-14	18,22
	Surface cracking where insulation boards not tightly abutted	Assure boards are tightly abutted per manufacturer's requirements	13-14	
	Improperly cured insulation boards	Assure insulation boards meet quality control requirements	13-14	
	Cracking tendency increased by improper alignment of insulation boards at window and door corners	Assure vertical board edges do not align with the vertical edges of door or window openings	13-14	20,21, 23a&b
	Installation over building expansion/control joints without corresponding expansion/control joints	Assure appropriate use of system expansion/control joints	13-14	

Table 1 (Cont'd)

Problem Category	Specific Problem Issue	Solution/Prevention	Corresponding References Text Page	Figure No.
System cracking (cont'd)	Surface area of PM systems exceeded without required system control joints	Assure uninterrupted surface area does not exceed manufacturer's requirements	13-14	
Design issues	Bridging over downspouts	Ordinarily downspouts should be exposed and accessible; if bridging is necessary, EIFS must be independent of downspout	14-16	24,25,27
	Use of EIFS for flat, horizontal sections increasing the potential for system damage due to hail or standing water	Horizontal sections of EIFS must be sloped for water run-off; if flat, the top section of a parapet wall must be capped with metallic flashing	15-16	14,26
	Use of insulation boards over 4-in. thick	Do not use insulation boards greater than 4-in. thick until further studies determine acceptable use	15-16	20,21
	Use of EIFS in loading dock areas or where the potential for damage is high	Use of EIFS immediately in the vicinity of loading docks and doors is not recommended; use other wall materials more resistant to the activities present; other areas besides loading docks prone to impact damage should either have high impact systems applied or use other wall materials	12,15,16	12,13
	Considerations for use of EIFS over gypsum sheathing (i.e., system must be mechanically attached) because of possible system delamination caused by degradation of the sheathing from water infiltration	Follow manufacturer's most current installation details	15-17	
	Dark-colored EIFS absorbs more heat, exaggerating system movement due to thermal effects; also dark colors show fading and surface staining from aluminum fixtures more than light colors	Dark colors for EIFS should be avoided wherever possible	16	19

Table 1 (Cont'd)

Problem Category	Specific Problem Issue	Solution/Prevention	Corresponding References Text Page	Corresponding References Figure No.
Construction deficiencies (Also see system cracking)	Integrity of existing substrates and substrate surfaces (i.e., dirty, chalky, peeling, crumbling or in otherwise poor condition)	Substrate wall must be clean, dry, firm and otherwise suitable for the purpose; prepare surface per manufacturer's guidance; for previously painted surfaces, complete removal of old paint is recommended; in lieu of sandblasting, a wire metal lath may be used or direct mechanical attachment of the EIF system	17,19	28,29,32
	Surface condition of newly constructed wall surfaces	Follow manufacturer's guidance on acceptable substrate materials for a particular system; the surface must be clean, dry, firm and otherwise suitable for the purpose	17,19	
	Integrity of gypsum sheathing exposed to the weather	Perform the quality assurance peel test described in the text; replace defective boards	17,19	
	Insufficient adhesive contact area	Assure applicators use appropriate notched trowel to apply adhesive and work the boards into the substrate to achieve a minimum 50 percent contact area	17,19	
	Incorrect caulking backer rod used. Also incorrect caulking material or omission of required primer	Verify that the applicators are using closed-cell backer rods; determine if caulking materials meet manufacturer's specifications; assure caulking primer is used if required	17,19,20	30
	Insufficient thickness of base coat and/or improperly embedded reinforcing fabric	Routinely check to assure that applicators apply required thickness of base coat per manufacturer's specifications; reinforcing fabric must be completely embedded (i.e., no bare fabric)	18,20	
	Insufficient overlap of reinforcing fabric	Assure a minimum overlap of 2-1/2 in. or as otherwise required by the manufacturer	18,20	

Table 1 (Cont'd)

Problem Category	Specific Problem Issue	Solution/Prevention	Corresponding References Text Page	Corresponding References Figure No.
Construction deficiencies (cont'd)	Complete omission of reinforcing fabric	Assure applicators place the specified type and weight of reinforcing fabric	18,20	
	Poor detailing around building penetrations	Assure that no exposed board edges or gaps exist between the system and penetration; follow manufacturer's recommended practices for finishing	18,20	31
	Also see category on system cracking for further construction deficiency examples			

4 DISCUSSION

The system problems experienced by EIFS do not imply it is an unacceptable exterior cladding. On the contrary, site inspections have documented successful EIFS applications on military facilities. Most of the problems observed were relatively minor and correctable assuming timely repair procedures are done (Table 1). In fact, the Army and Air Force success rate is high mainly because the systems are being specified and used as originally designed, that is, to upgrade existing masonry buildings. In the private sector, the systems are extensively used for new construction over steel studs and gypsum sheathing. Since additional precautions are necessary when applying the systems over gypsum sheathing, routine use of EIFS in future new building construction on Army installations will require that the Corps address this issue further.

For the present, inspection during the construction stages is of primary importance. Inadequate inspection was the primary factor in most major system failures documented on Army facilities. With the knowledge and understanding of common failures, construction inspectors will be better prepared to assure good quality EIFS installation.

Another consideration is the need for proper and timely maintenance and repairs. Damaged or deteriorated sections must be repaired before sufficient moisture intrudes the system to cause additional system problems and failures or even deterioration of the substrate wall.

5 CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Exterior insulation and finish systems are a relatively new building cladding system available in the United States. EIFS offer many advantages such as good insulation properties, cost efficiency and pleasing appearance. As with any new technology, there is a learning curve for understanding proper use and the inherent product limitations.

The four main problem areas with EIFS experienced by the Army are:

1. Mechanical damage
2. System cracking
3. Design issues
4. Construction deficiencies.

Even though these problems can be found on Army (and Corps-designed Air Force) installations, most of these problems are minor, and correctable by relatively simple maintenance and repair procedures.

An awareness of the major problem areas, and adherence to proper construction and maintenance techniques should help lessen the occurrence of these minor problems and should also help prevent a repeat of the few more serious failures that have occurred.

Recommendations

It is recommended that:

1. High impact EIFS should be defined and specified for trafficked areas. It should be noted that no standardized guidance is yet available to compare different manufacturers' high impact EIFS.

2. For areas where mechanical damage is inevitable, another siding material should be used in place of or over the EIFS. Solid masonry, brick, or wood paneling (wainscot) can be architecturally blended into the wall at anticipated problem areas.

3. Doorstops must be used and appropriately positioned to avoid damage resulting from doors or door handles striking the system.

4. Damage caused by lawn mowers can be lessened by providing gravel rock borders around buildings with EIFS.

5. EIFS should not be applied as roofing or in horizontal applications. In those instances where EIFS must be applied to horizontal surfaces, the surface should be sufficiently pitched so that water cannot accumulate.

6. EIFS should not be finished with dark colors, which may exaggerate system movement due to thermal effects.

7. Gutters and downspouts should not be concealed by the EIFS. Where EIFS must bridge downspouts, the system should not be adhesively attached to the system.

8. Care should be taken to follow manufacturer's guidelines and Corps of Engineers Guide Specification CEGS-07240 in the application of EIFS, especially in:

a. The type and quality of insulation boards
b. The use of reinforcing fabric
c. The thickness of EIFS application
d. The detailing around building fixtures.

APPENDIX:

FURTHER INFORMATION

An overall look at EIF systems is presented in the draft video, *Should I Use Exterior Foam Insulation?* (1990), sponsored by the Facilities Engineering Applications Program (FEAP) and coproduced by Steve Flanders of the U.S. Army Cold Regions Research and Engineering Laboratory (USACRREL) and Richard Lampo of USACERL. This video discusses benefits and potential problems of EIFS.

As part of a Technology Transfer Test Bed (TTTB) Program effort (work unit TTTB-EM-BR9), the Omaha District Corps of Engineers is currently involved in a demonstration project, titled *Investigation of Exterior Insulation and Finish Systems.* The draft report, *Exterior Insulation and Finish System Study (EIFS)*, provides further guidance on proper and improper use and applications of EIFS. The final report should be completed and ready for distribution this fiscal year, and will be available for purchase through the National Technical Information Service, Washington DC, (804) 487-4600.

In recognition of the needs of the field personnel responsible for various aspects of this technology, USACERL is currently developing a set of Technical Manuals covering design, construction, inspection, and maintenance/repair of EIFS (Reimbursable Project No. E87890367 from the U.S. Army Engineering and Housing Support Center, Fort Belvoir, VA 22060; USACERL Work Unit D59, "Prepare, Design, Installation Inspection, and Maintenance/Repair Manuals for EIFS Used in Retrofit Applications").

The report authors are also participating in an American Society for Testing and Materials (ASTM) project to help develop an industry consensus for EIFS standards. In cooperation with ASTM, USACERL is conducting impact tests on EIF systems to develop an industry-accepted test method to determine impact resistance and establish standard definitions and classifications for impact resistance to help designers or specifiers define and compare high impact systems (Project 4A162731AT41, "Military Facilities Engineering Technology"; Work Unit MA-CR0, "Design Concepts Using Advanced Materials.")

The following Corps-initiated references specifically address energy-related matters:

Flanders, Stephen N., "In-situ Assessment of Two Retrofit Insulations," in *Thermal Performance of the Exterior Envelopes of Building*, Geschwiler et al., eds. (American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. [ASHRAE], Atlanta, 1986), pp 32-34.

Flanders, Stephen N., "In-situ Measurement of Masonry Wall Thermal Resistance," *ASHRAE Transactions*, Vol 88, Part 1, 1982.

Rundus, Richard E., *Thermal Performance of Retrofit Exterior Insulation and Finish Systems on L-Shaped (Type 64) Barracks*, draft Technical Report (USACERL, 1990).

Rundus, Richard E., *Selection of External Insulation and Finish System for Energy Conservation Project on L-Shaped Barracks*, draft Engineer Technical Note (USACERL, 1990).

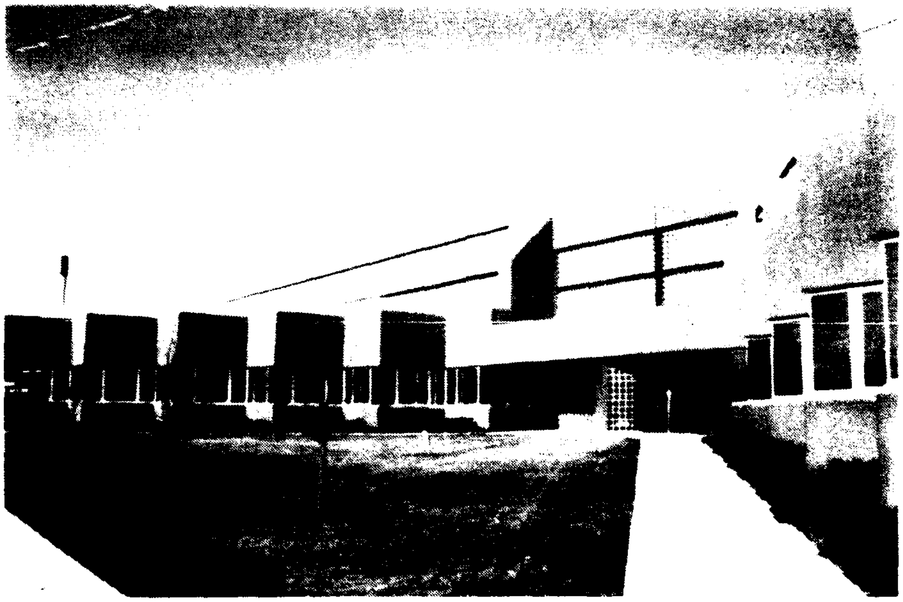

Figure 1. EIFS used on new construction.

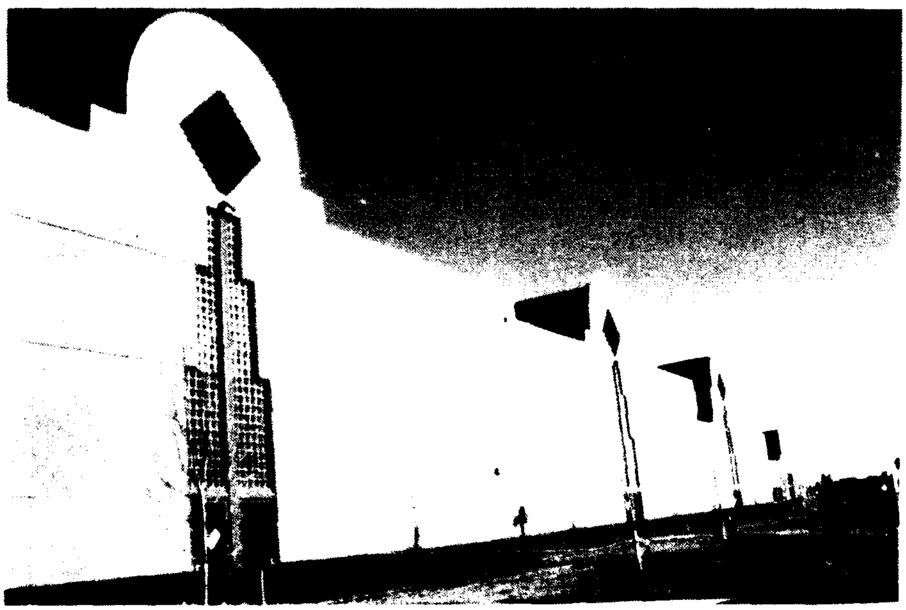

Figure 2. Use of EIFS in modern building architecture.

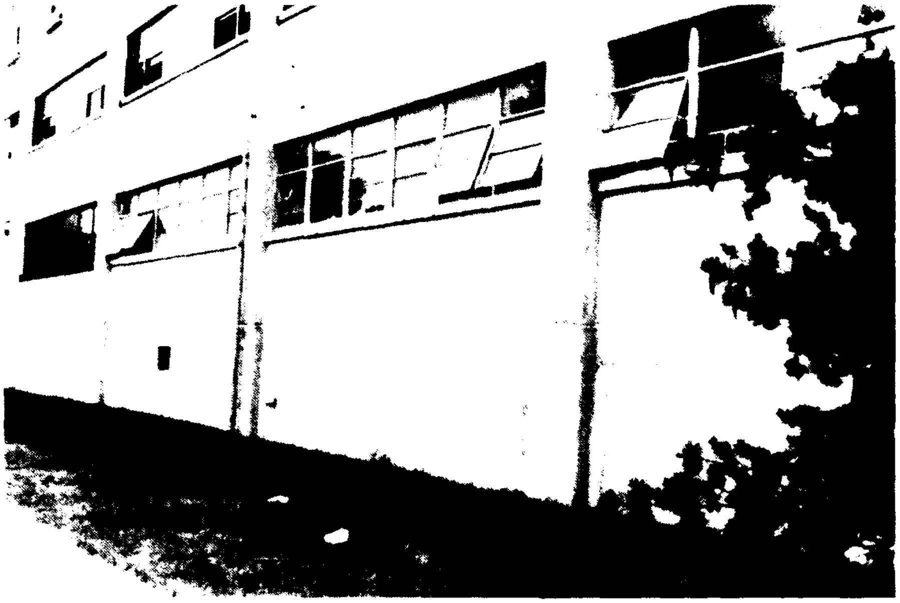

Figure 3. Typical aging masonry building on Army installations.

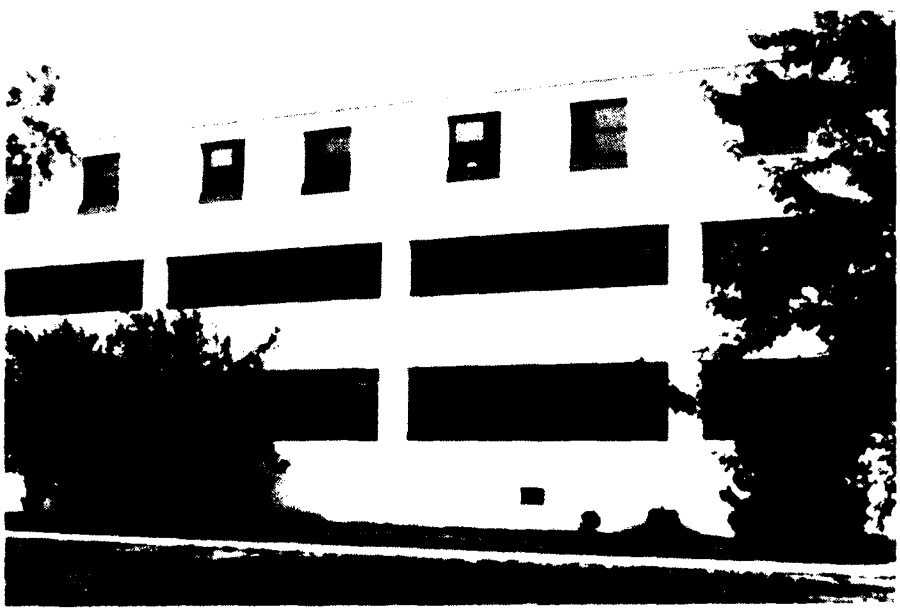

Figure 4. Masonry building retrofitted with EIFS.

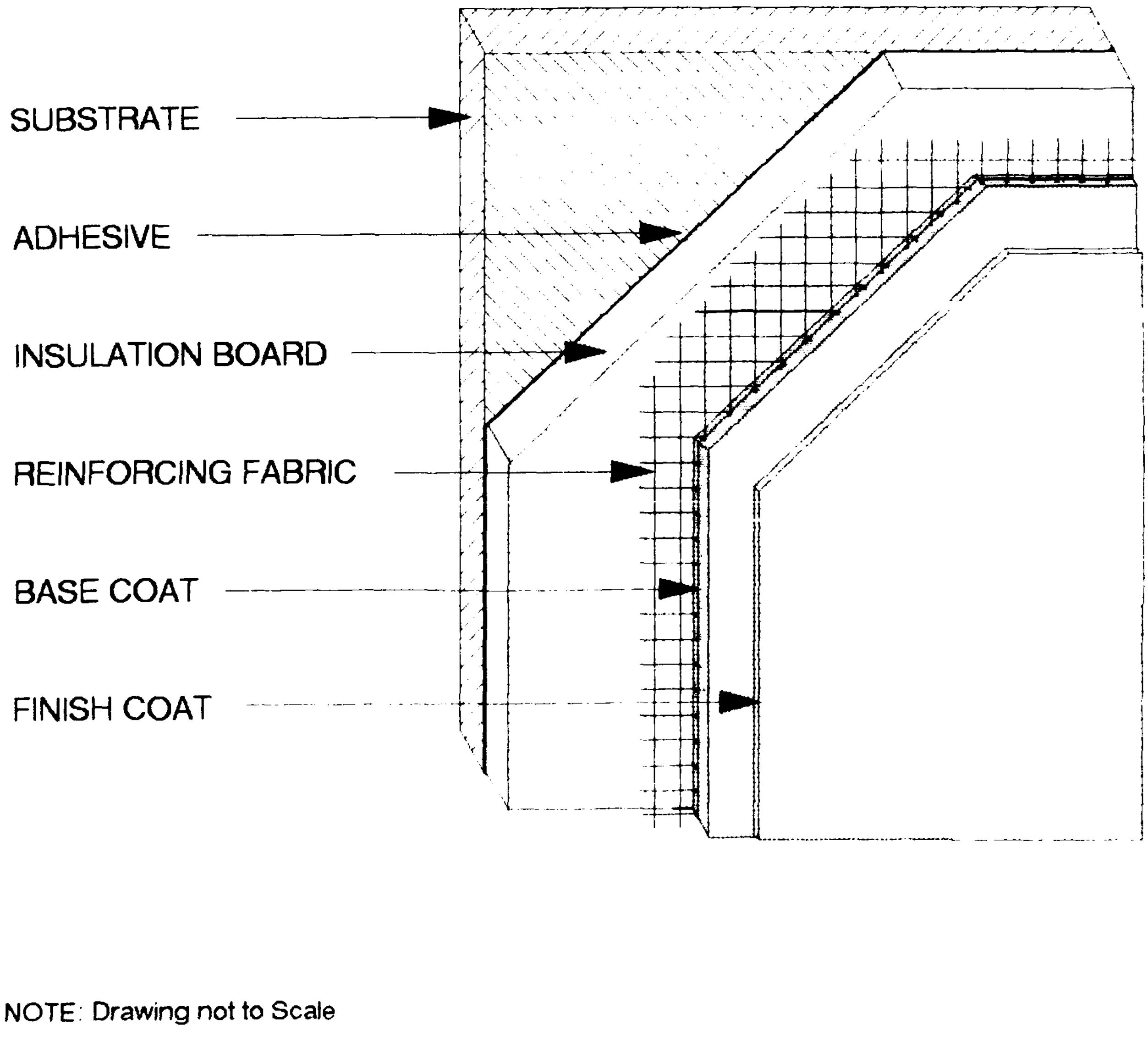

Figure 5. Components of a typical EIF system.

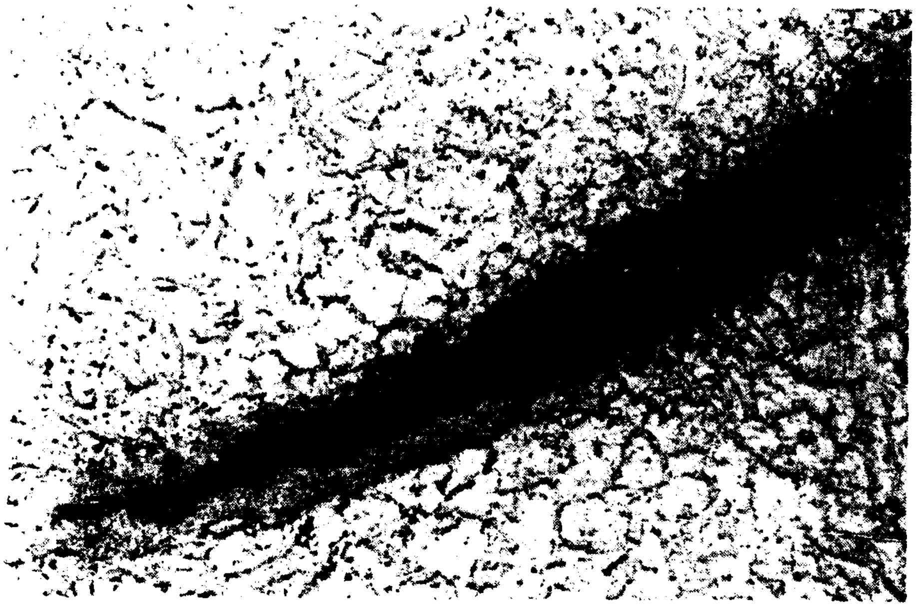

Figure 6. Exposed reinforcing fabric due to abrasion.

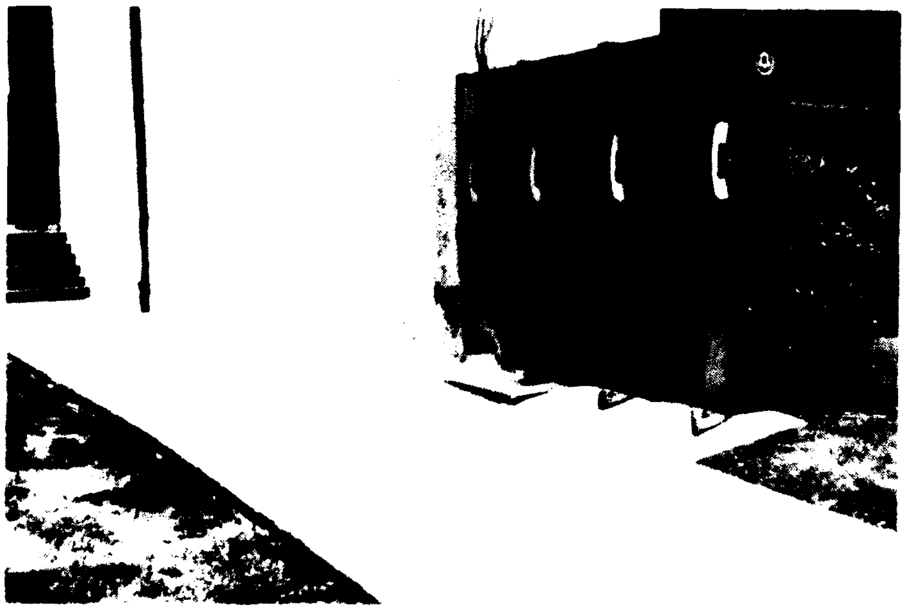

Figure 7. Damage due to EIFS around outdoor telephones.

Figure 8. Intentional damage caused by kicking.

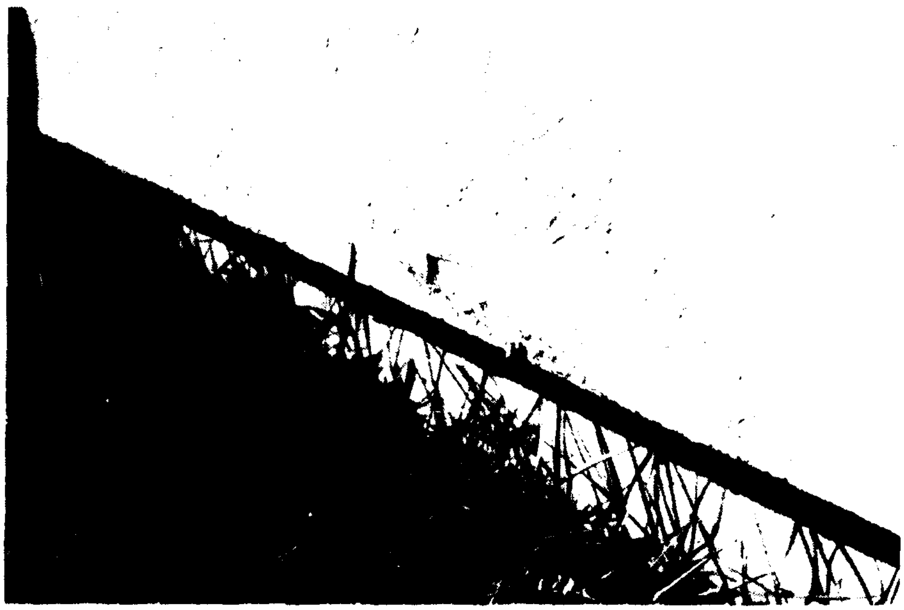

Figure 9. Damage caused by lawnmower.

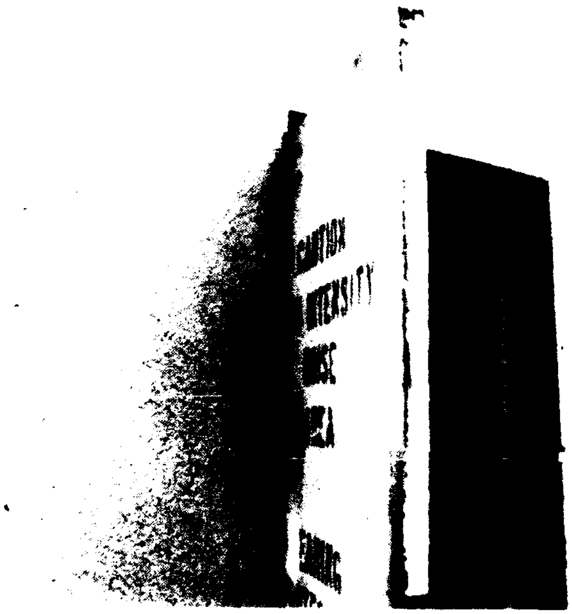

Figure 10. Door hitting edge of wall due to added thickness of EIFS.

Figure 11. Impact damage from door handle.

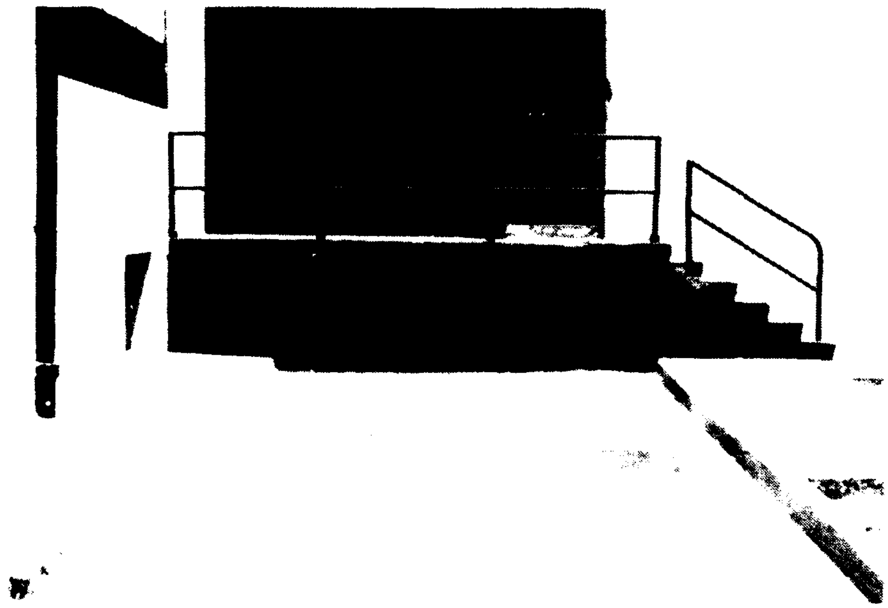

Figure 12. Damaged EIFS around loading dock.

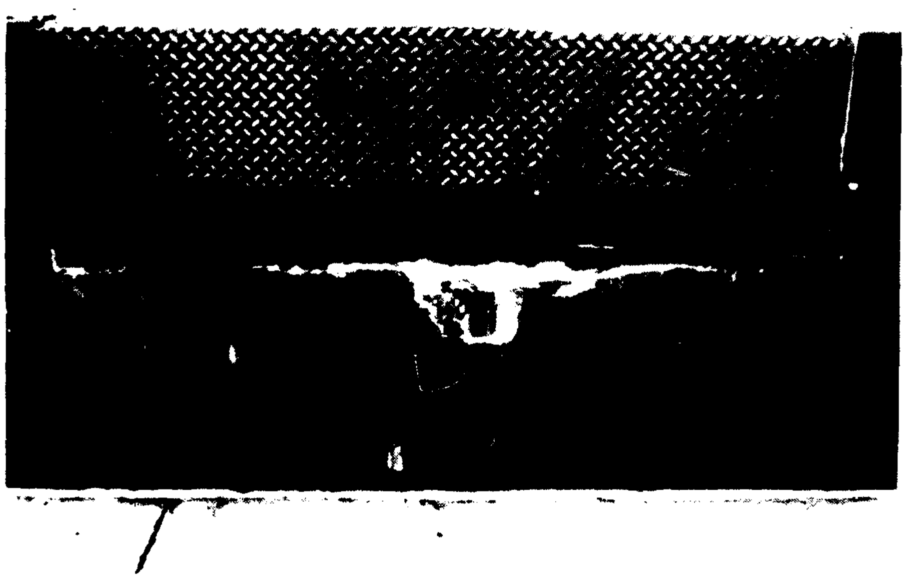

Figure 13. Typical damage seen around loading docks.

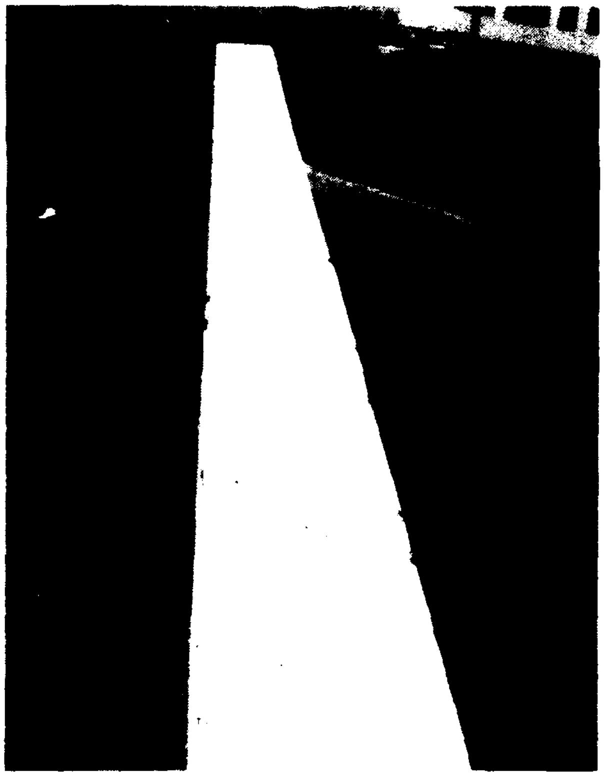

Figure 14. Hail damage on the top of parapet wall.

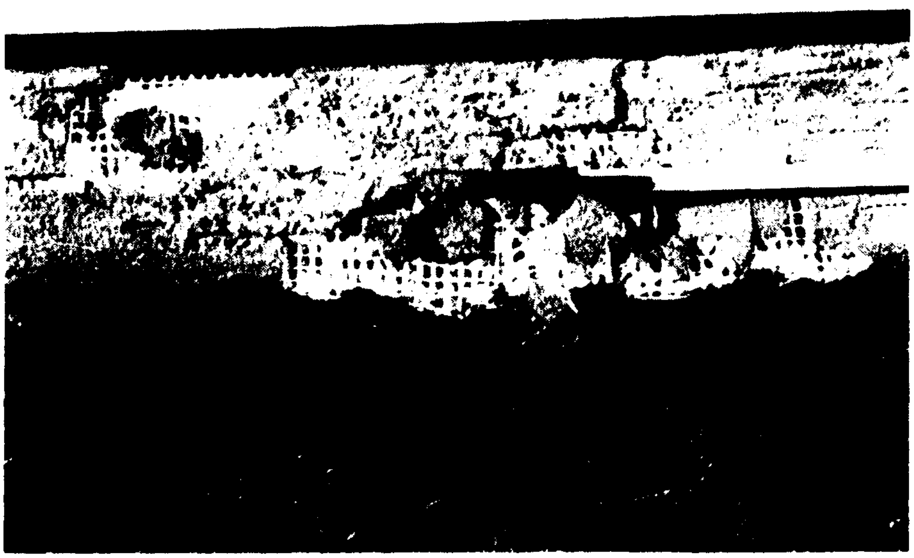

Figure 15. Damage along window sill area due to hail.

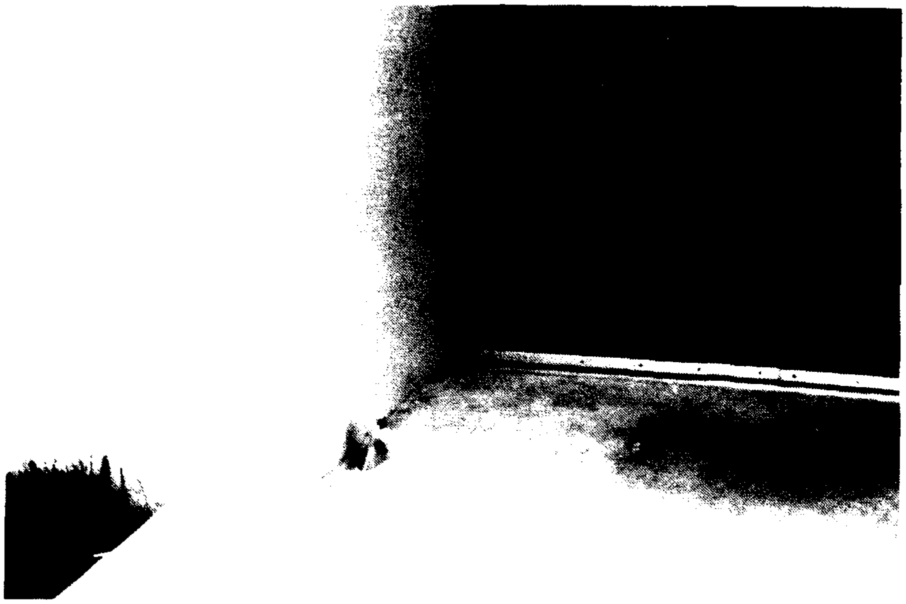

Figure 16. Doorstop placed to keep door from striking the EIF system.

Figure 17. Gravel border around building to keep lawn care equipment away from EIFS.

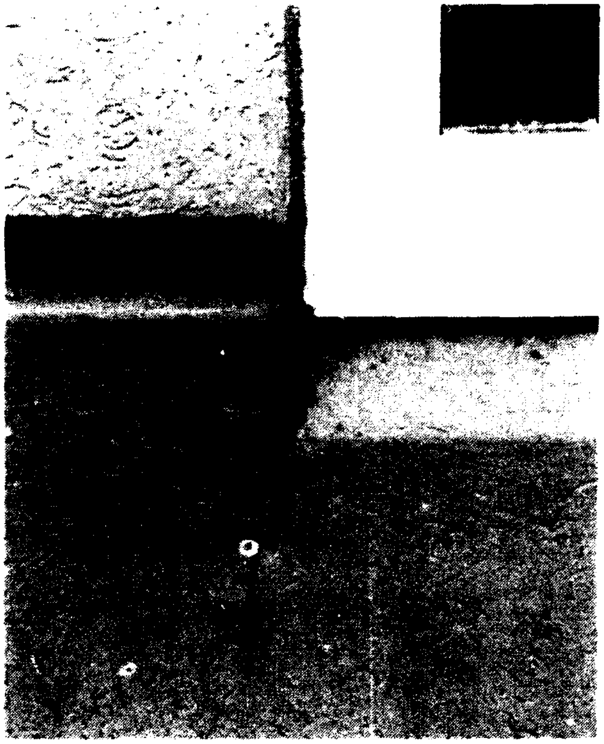

Figure 18. Typical cracking seen at window corners.

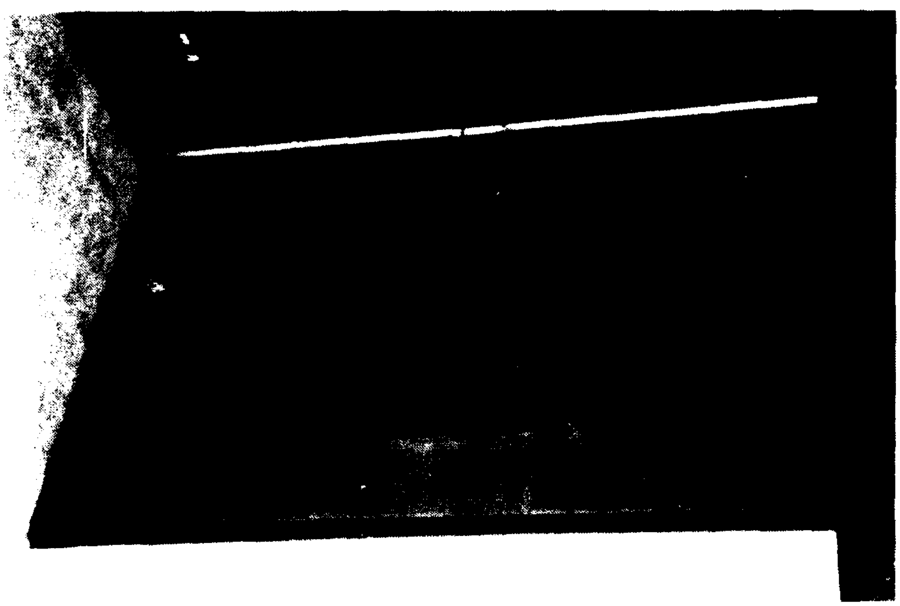

Figure 19. Cracks forming where underlying insulation boards were not tightly abutted.

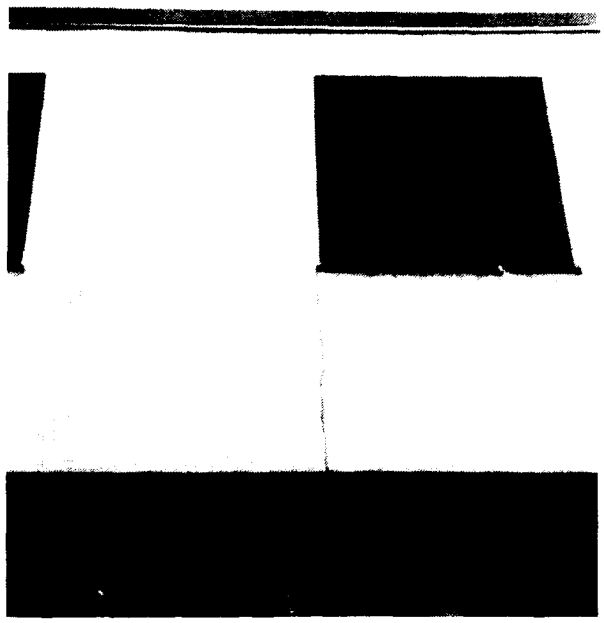

Figure 20. Cracking at window corners caused by improper system installation.

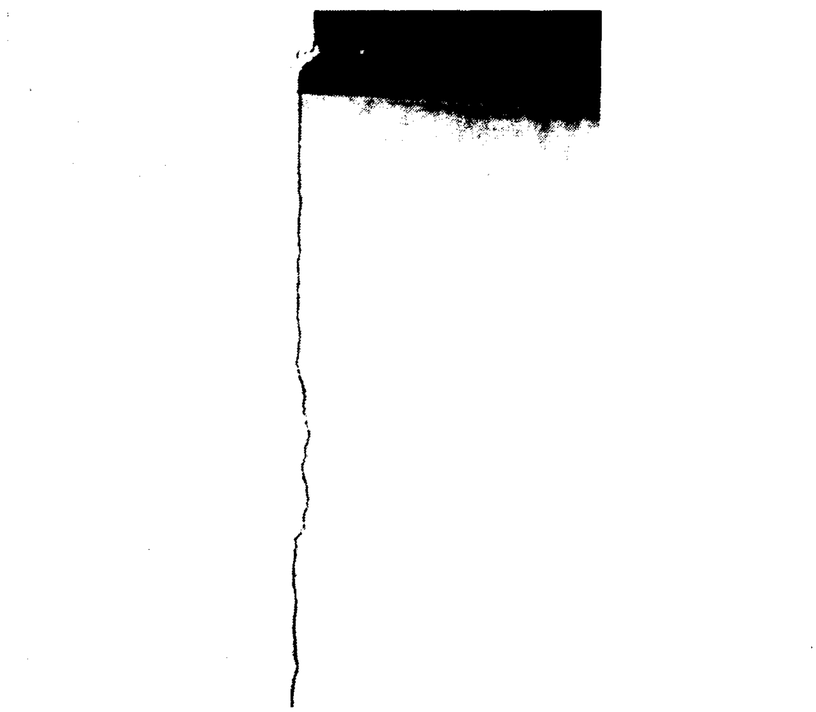

Figure 21. Closeup of lower crack shown in Figure 20.

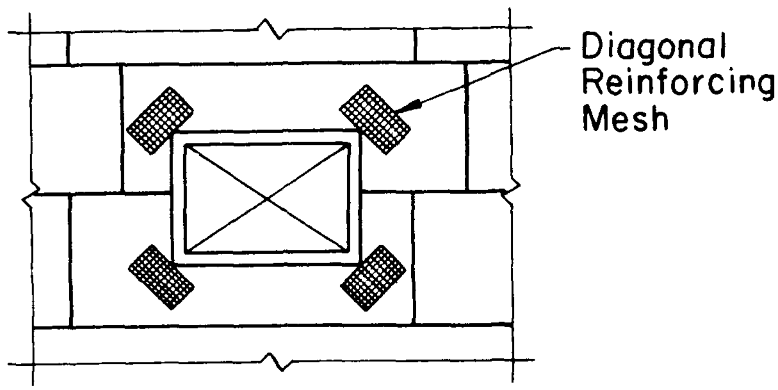

Figure 22. Schematic showing manufacturers' recommended use of diagonal reinforcing fabric at window and door corners. (This information was printed with the permission of Dryvit Systems, Inc., One Energy Way, P.O. Box 1014, West Warwick, RI 02893.)

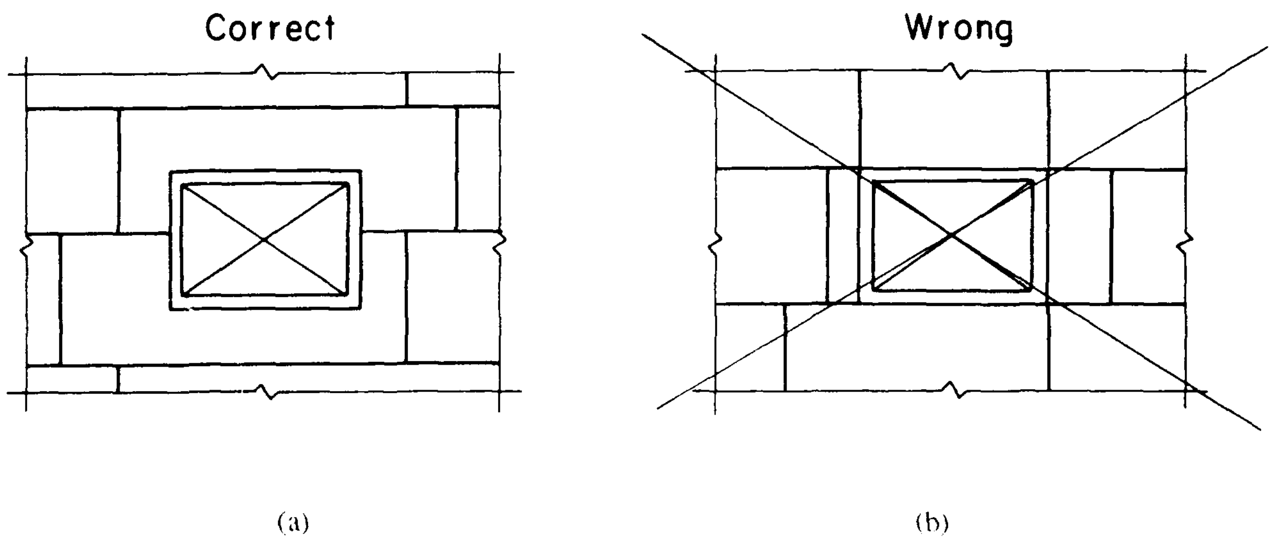

Figure 23. Insulation boards at window penetrations, placed (a) properly, (b) improperly. (This information was printed with the permission of Dryvit Systems, Inc., One Energy Way, P.O. Box 1014, West Warwick, RI 02893.)

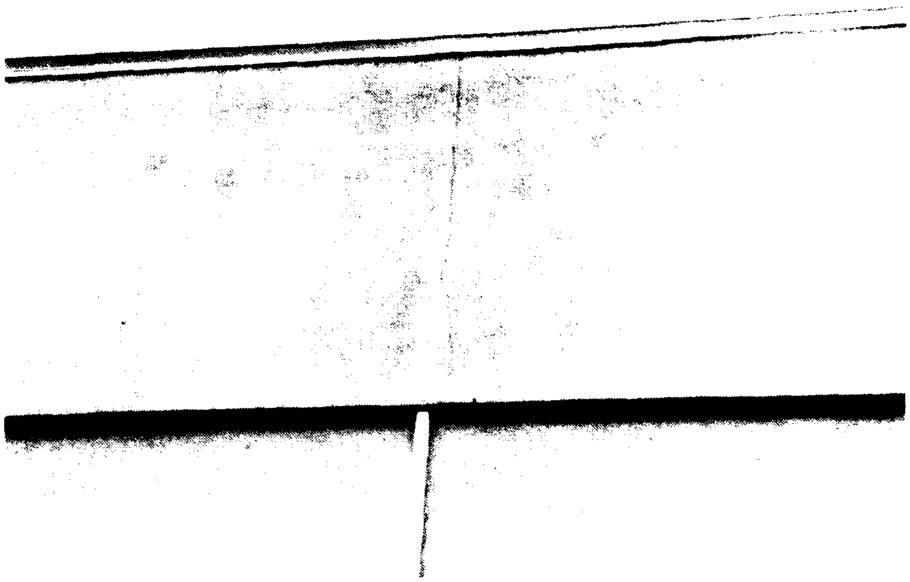

Figure 24. Cracking along embedded downspout.

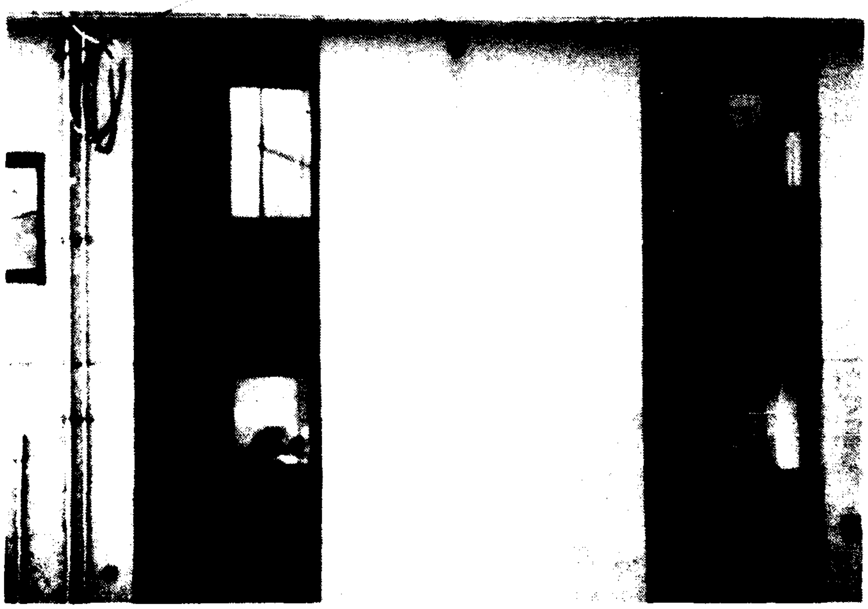

Figure 25. Water flowing directly onto and down system face due to missing downspout section.

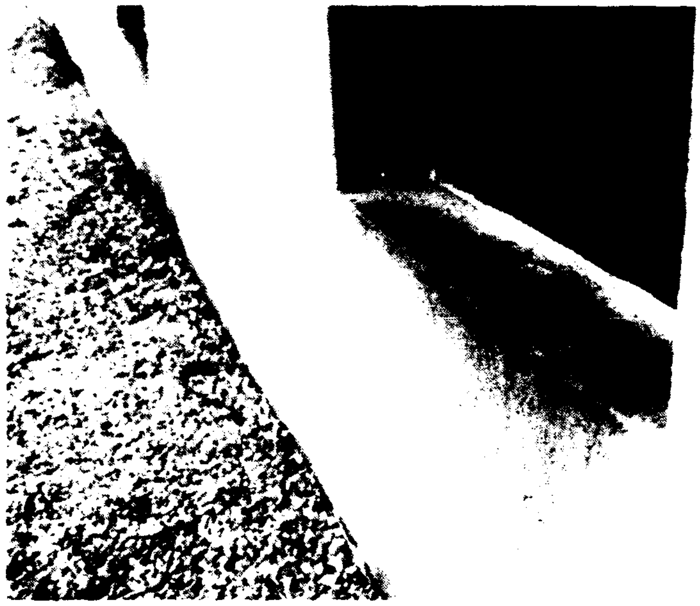

Figure 26. Algae growth caused by standing water in horizontal surface at window sill area.

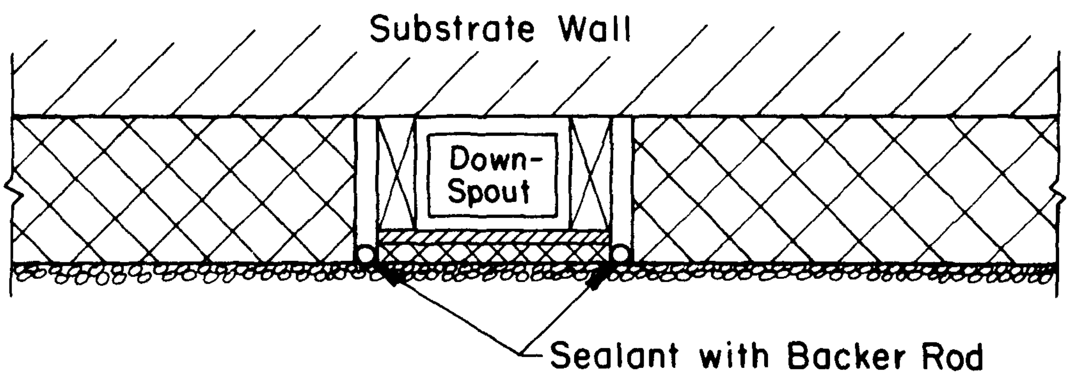

Figure 27. System detailing needed to bridge underlying downspout.

Figure 28. EIFS bowing away from substrate wall due to adhesive failure.

Figure 29. Excessively chalky surface to which attachment of EIFS was attempted.

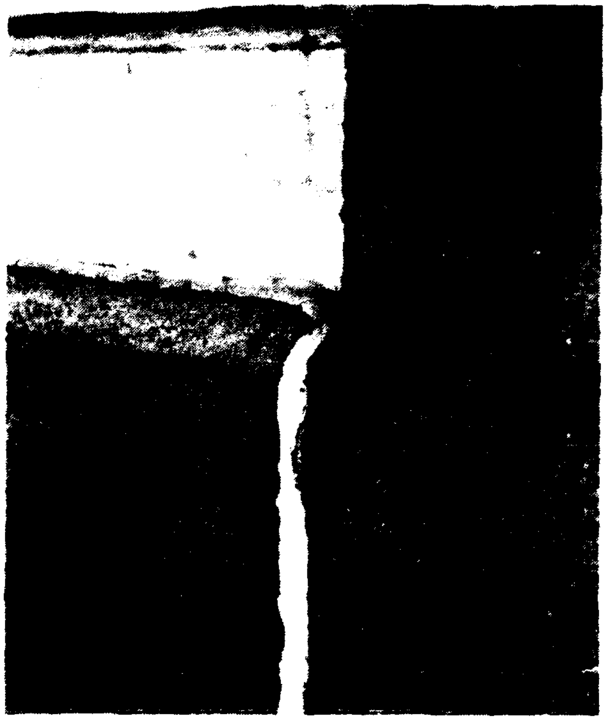

Figure 30. Failure of sealant joint where open-celled backer rod was used.

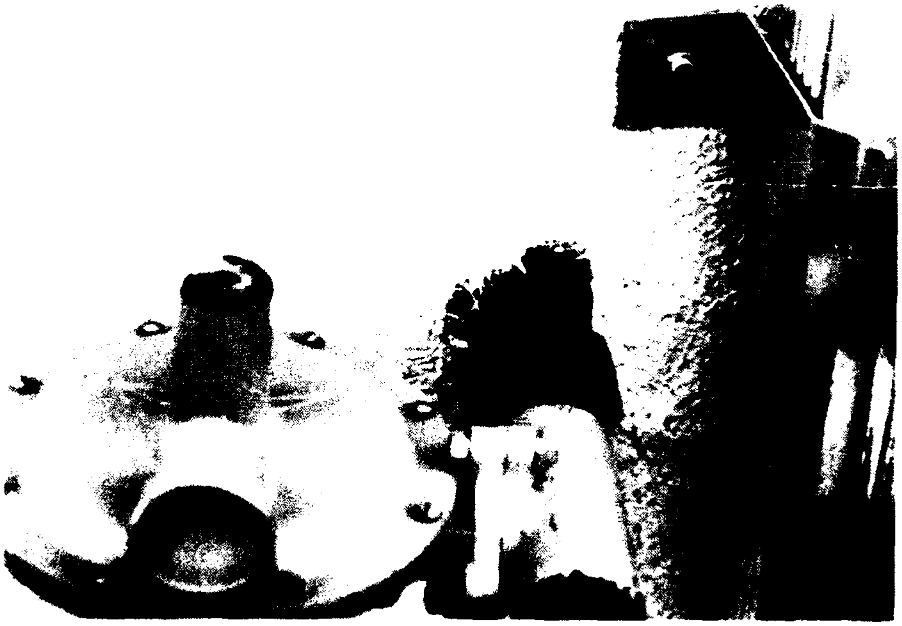

Figure 31. Poor system detailing around building fixture. (Photo courtesy of Kenney, Williams and Williams, Inc., Maple Glen, PA.)

Figure 32. Workman attaching wire metal lath over previously painted masonry.

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